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TENTH QUARTERLY REPORT

SOLAR THERMIONIC

GENERATOR DEVELOPMENT

THERMO ELECTRON

CORPORATION

Contract No. 951263 Report No. TE4055-176-68

Thermo Electron Corporation, 85 First Avenue, Waltham, Massachusetts 02154

TENTH QUARTERLY REPORT

SOLAR THERMIONIC

GENERATOR DEVELOPMENT

May 1968

Prepared for

Jet Propulsion Laboratory
Pasadena, California

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TENTH QUARTERLY REPORT

SOLAR THERMIONIC GENERATOR DEVELOPMENT

Summary

This report covers progress for the tenth quarter, corresponding to the period 1 March to 31 May 1968.

During this quarter, the fabrication and test of converter T-209 have been completed. This model was the second under this program to incorporate a collector-radiator heat pipe structure. The heat pipe design was changed substantially in order to remedy a choked heat pipe vapor flow condition observed in the previous model T-208, and subsequent tests showed that this objective was reached. Converter T-209 equalled the highest output observed from any of the rhenium-emitter and rhenium-collector converters fabricated under this program; however, during tests at high heat inputs, the output was found to deteriorate. This is the first instance of degradation experienced under this program, and it appears that it was caused by a leak of sodium vapor from the heat pipe into the converter envelope, which resulted in an increase of the collector work function of 0.17 eV. The mechanism responsible for the sodium leak is not known. The recommendation has been made to JPL to fabricate T-210 based on a design identical to that of T-209, so that subsequent tests may determine whether the design of the heat-pipe to converter interface possesses an inherent weakness. Also during this quarter, the layout of the 16-converter generator was completed, and the design is now ready for the preparation of detailed drawings.

Design of Converter T-209

The design approved by JPL for the fabrication of converter T-209 is shown in Figure 1. The differences between this design and that of the previous model T-208, shown in Figure 2, are as follows:

a. The heat pipe is longer by one inch, increasing the radiator area by 36%, from 38.3 to 52.0 sq cm.

b. The outgassing groove on the collector face has been eliminated, yielding a collector area of 2.34 sq cm.

c. The capillary support at the back of the collector had a webbed design, shown in view A-A of Figure 1, instead of the perforated plate, shown in view A-A of Figure 2, which allowed a much larger flow cross section for the heat pipe vapor, and which was intended to avoid the large temperature drop at the liquid-vapor interface found in converter T-208 discussed in the 9th Quarterly Report.

d. The capillary mesh screen is made of niobium instead of stainless steel, and the mesh number is 100 instead of 400 because of the unavailability of niobium wire smaller than 0.0035 in. in diameter. Both the T-208 and T-209 designs use 2 wraps of mesh material.

e. The rhenium collector face is attached to the niobium substrate by pressure-bonding instead of vanadium brazing.

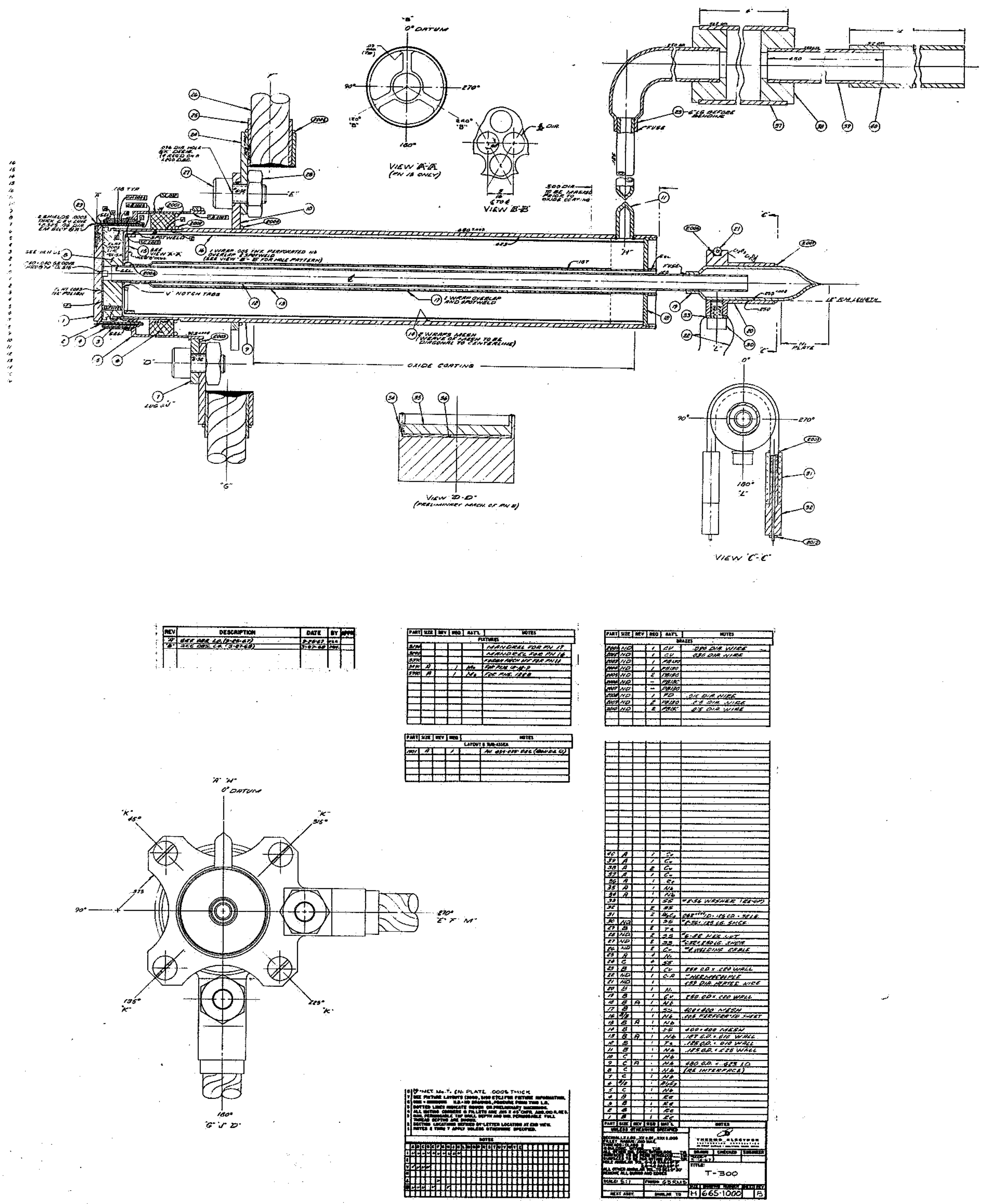

Figure 1

THERMO ELECTRON CORPORATION

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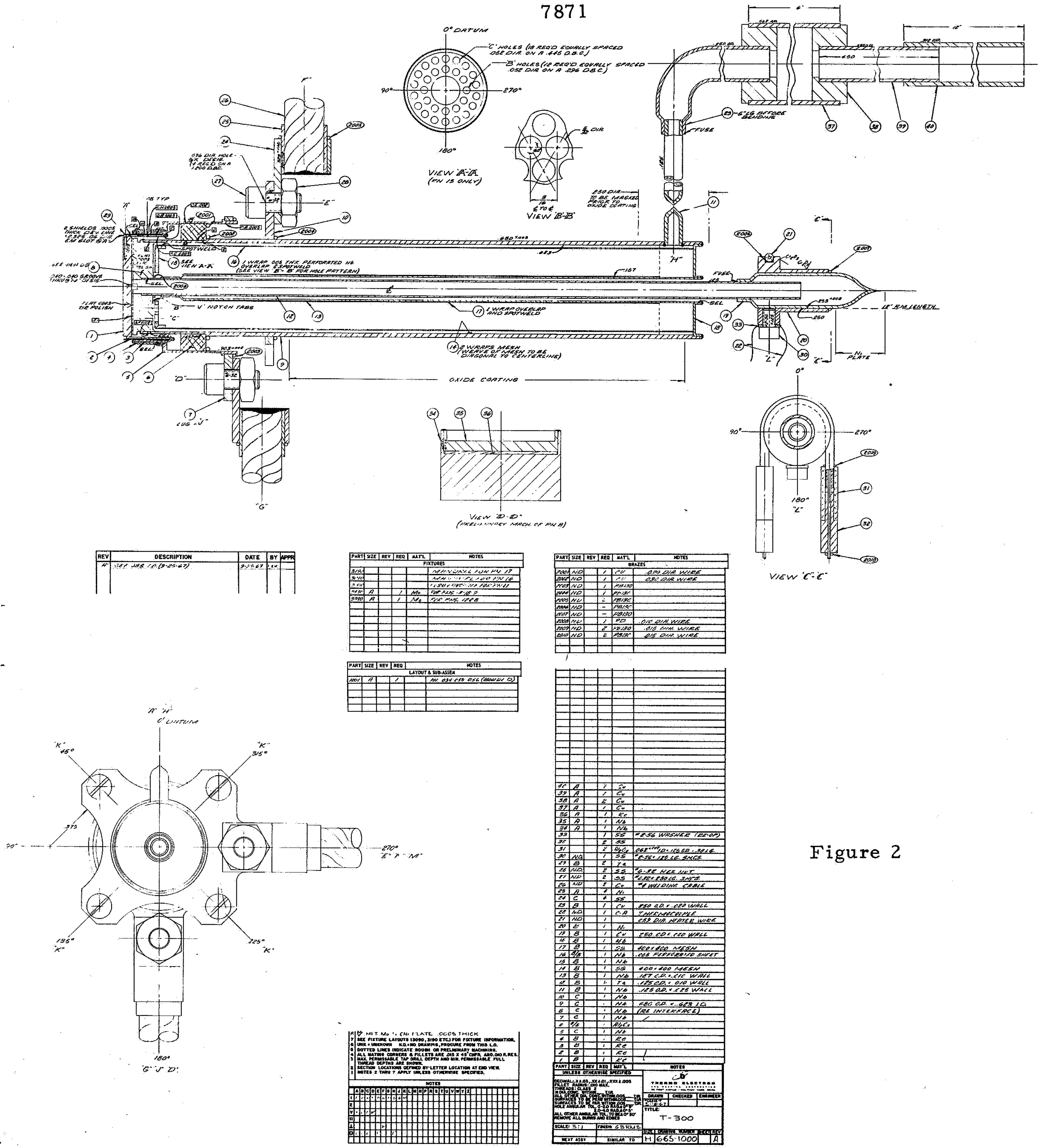


Figure 2

It had also been suggested to JPL to fabricate T-209 with an 0.200-in.-thick emitter structure so as to explore the effect of emitter thickness on emitter temperature measurement accuracy, but JPL expressed a preference to retain the thin emitter configuration (0.060 in. thick) because it minimizes the temperature drop across the thickness of the emitter piece.

Fabrication of Converter T-209

The fabrication of the converter encountered no significant difficulties. As in T-208D, the cesium tube was made of 0.025-in.-wall niobium instead of 0.010-in.-wall tantalum. It was found that the weld of the inner heat pipe tube to this tube requires careful control; otherwise, the cesium tube can melt. The use of a thin (0.020-in-. dia) thoriated tungsten electrode was found to be particularly helpful.

Initial fabrication efforts included exploring the problems of electron beam welding a thick (0.200-in.) emitter to the emitter support assembly, and it was found difficult to produce a leak-tight weld because of the dissimilarity in cross section of the parts joined. Attempts to obtain a leak-tight weld were not pursued.

The standard emitter (0.060 in. thick) used for the fabrication of T-209 was electroetched with the same procedure used for T-208 (1 minute at 5 volts). It was then thermally stabilized for 2 hours at 1990°C observed (approximately 2020°C true temperature). The emitter flatness was checked after thermal stabilization and the maximum deviation measured was 0.0006 in. The corresponding value for T-208D was 0.0004 in., which was incorrectly reported in the Ninth Quarterly as 0.004 in.

The capillary structure insertion required an 0.006-in. reduction in the diameter of the capillary support mandrel in order to accommodate a double wrap of 100-mesh niobium capillary screen.

Since the measured interelectrode spacing of converter T-208D was somewhat larger than normally expected (2.2 mils vs. a design value of 1.80 mils), it was deemed prudent to insure that the collector would be in intimate contact with the emitter surface during the final braze operation of converter T-209, and this was accomplished with the use of a small molybdenum weight.

The heat pipe portion of the envelope was outgassed for 8 hours at an average temperature of 500°C. The remainder of the sodium-fill operation was performed in the same manner as used for T-208D.

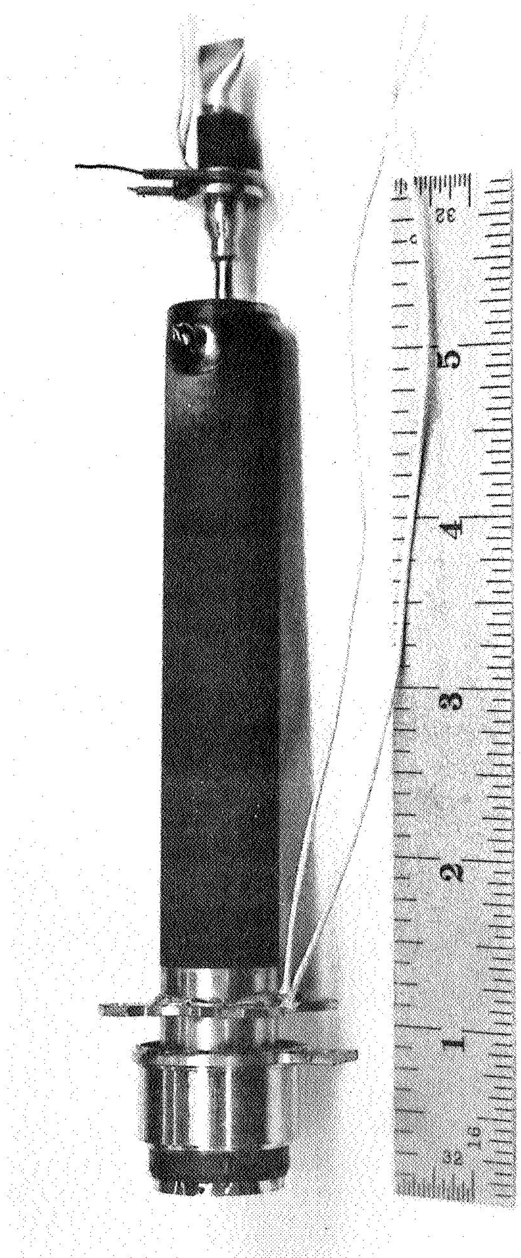
Converter outgassing was performed with care so as not to expose the converter envelope to elevated temperature conditions before the internal gases were pumped out through the small interelectrode gap. Cesium distillation was carried out at 200°C for 4 hours.

The completed model is shown in Figure 3, and as indicated there, its weight was 110 grams.

Test of Converter T-209

Converter T-209 was tested with a special double-spiral electron-bombardment filament shown in Figure 4. This filament shape was selected to achieve a more uniform heating of the emitter piece.

The converter test consisted of 8 runs as follows: Runs 1 to 3 to map the output under dynamic conditions at 2000, 1900 and 1800°K; Run 4 to measure cesium conduction for interelectrode spacing



110 GR.

Figure 3

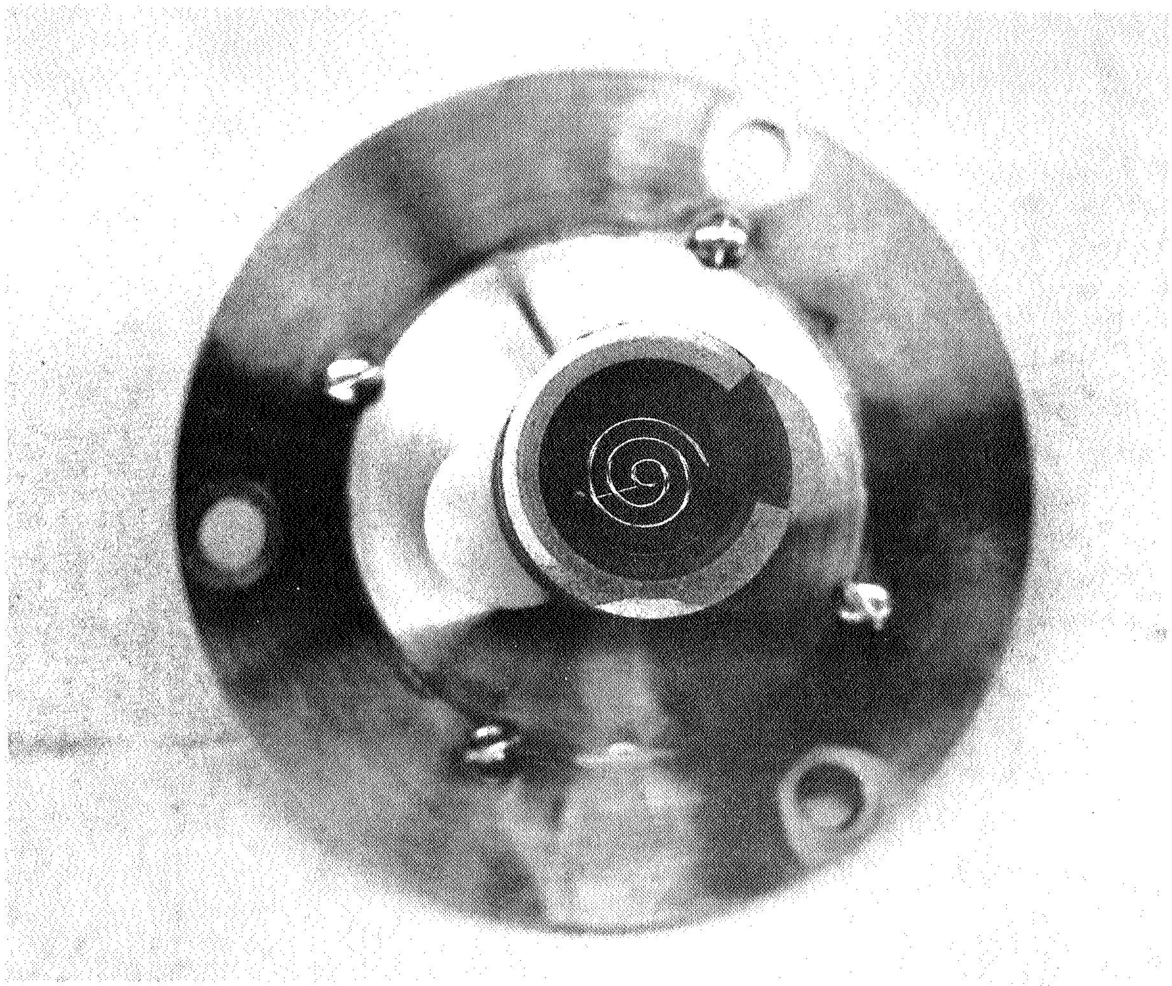


Figure 4

determination; Runs 5 to 7 to map the output under static conditions at 1700, 1600 and 1800°C, and Run 8 to ascertain the magnitude of a suspected change in collector work function. The Appendix presents the data and I-V traces collected during test.

In converter T-208 it had been found that with the use of the heavier 0.025-in.-wall cesium tube, the cesium reservoir had a tendency to overheat. In T-209, it was found that the lengthening of the heat pipe had lowered the general level of temperatures in the converter, to the extent that the reservoir overheating problem was solved.

Figure 5 shows the optimized I-V characteristics; the solid lines were obtained under dynamic testing, and the dashed lines were obtained under static load.

Figure 6 is a plot of the cesium conduction data, which is compared with that of T-206 and T-208.

Interpretation of Converter T-209 Test Results

As in the case of converter T-208, it is of interest to compare the performance of T-209 with that of T-206, because both converters have rhenium electrodes. In making the comparison, however, the ratio of collector areas of these two converters, which are 2.34 sq cm and 2.52 sq cm, respectively, should be accounted for. Figure 7 gives the optimized I-V traces for T-206, T-208 and T-209, where both the T-208 and T-209 traces have been sealed up by the respective collector area ratios of 2.52/2.16 and 2.52/2.34. On the basis of this figure, converter T-206 would appear to have better performance than T-209. Since such comparisons have often been found to be misleading

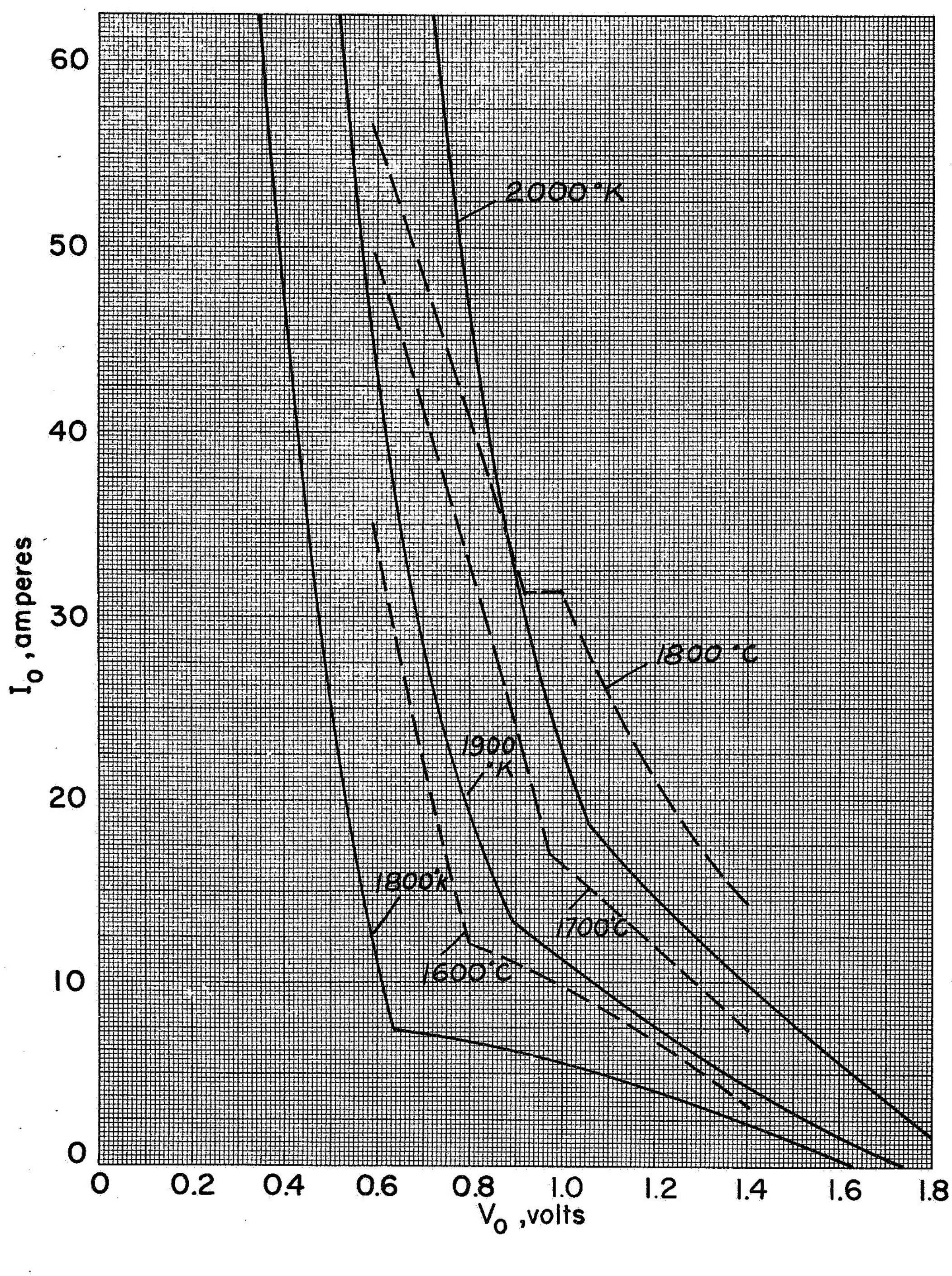

60
50
40
30
20
10
0
I_o, amperes
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts
2000°K
1800°C
1900 °K
1800°K
1700°C
1600°C

Figure 5

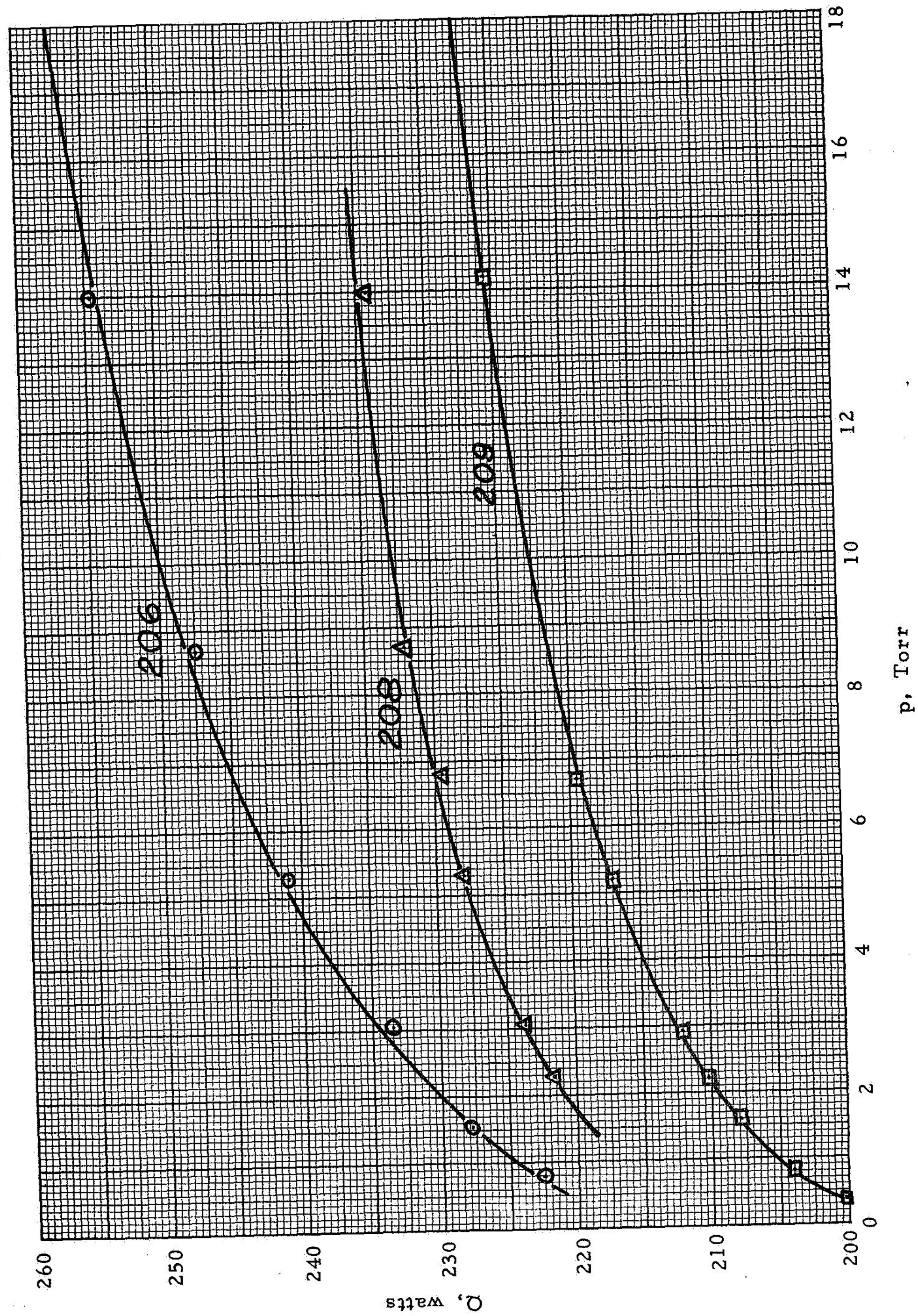
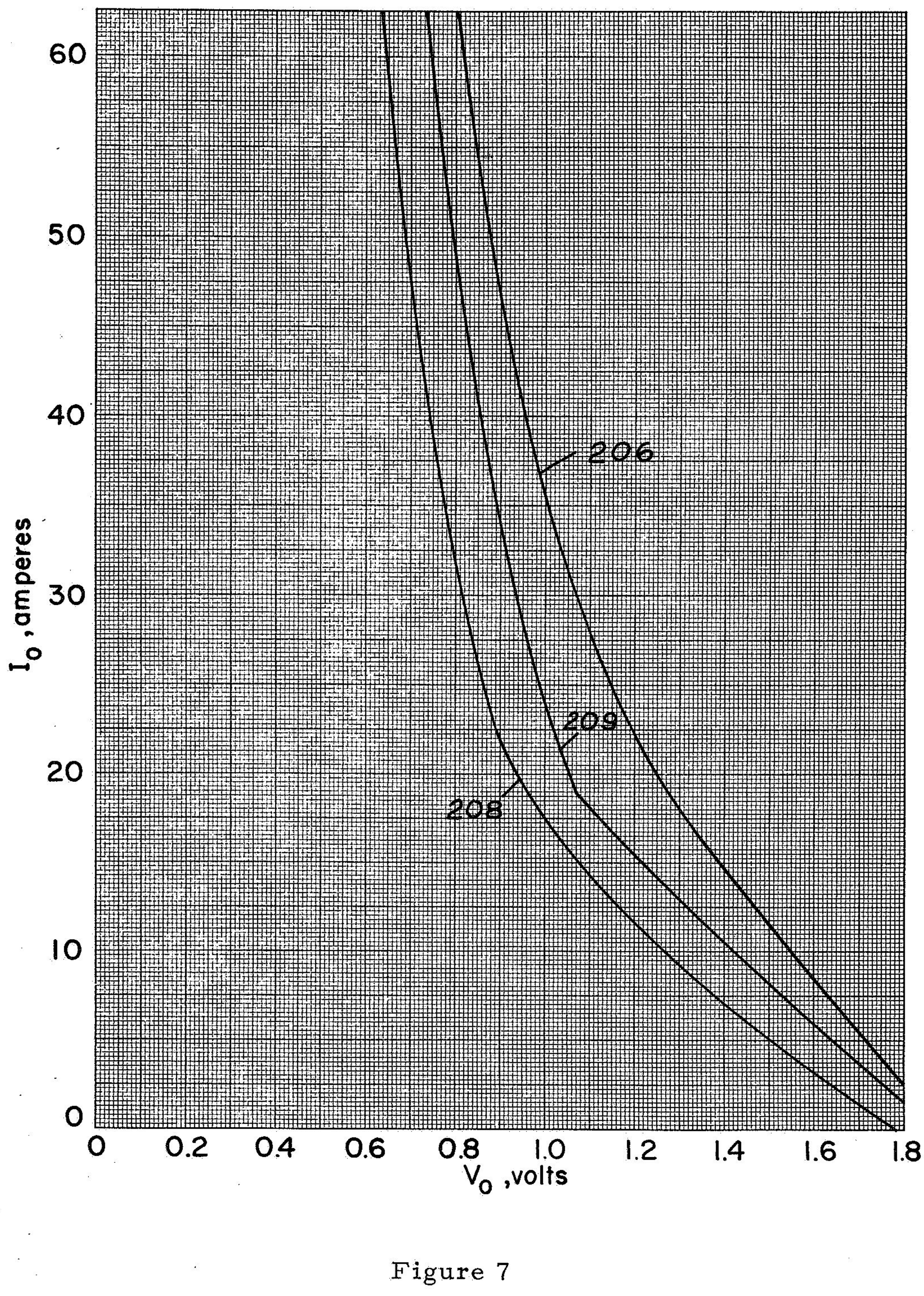

206
208
209
Q, watts
260
250
240
230
220
210
200
p, Torr
0
2
4
6
8
10
12
14
16
18

Figure 6



60
50
40
30
20
10
0
I_o, amperes
206
209
208
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts

Figure 7

because they include unreliable emitter temperature measurements, it is well to compare performances on a thermal input basis, and this is done in Figure 8. The comparison of T-208 with T-206 on this type of plot, shown in the Ninth Quarterly Report, had proven that Converter T-208 had a definitely lower output than T-206. Figure 8 shows that this is not the case for T-209, which has the same output as, or slightly higher output than converter T-206. Thus, within the current capability to measure converter performance, it appears that converter T-209 is as good as converter T-206.

The cesium conduction data given in Figure 6 was analyzed with the slope method previously outlined, and it was found that the interelectrode spacing of converter T-209 was essentially the same as that of T-208. The calculations are as follows:

	208		209	
p, torr	8	12	8	12
A, cm^2	2.16		2.34	
T_E, °K	2000°K		2000°K	
T_C, °K	880	885	800	800
$\partial Q/\partial p, \frac{\text{watts}}{\text{torr}}$	0.90	0.50	1.13	0.58
d, mils	2.06	2.33	1.90	2.32
Average d, mils	2.19		2.11	

As is evident in the data (sheet 5), in Figure 5 at 1800°C, 1.0 volt, and in Figure 8 at 366 watts, the output of converter T-209 was found to degrade during the high heat-transfer tests at 1800°C.

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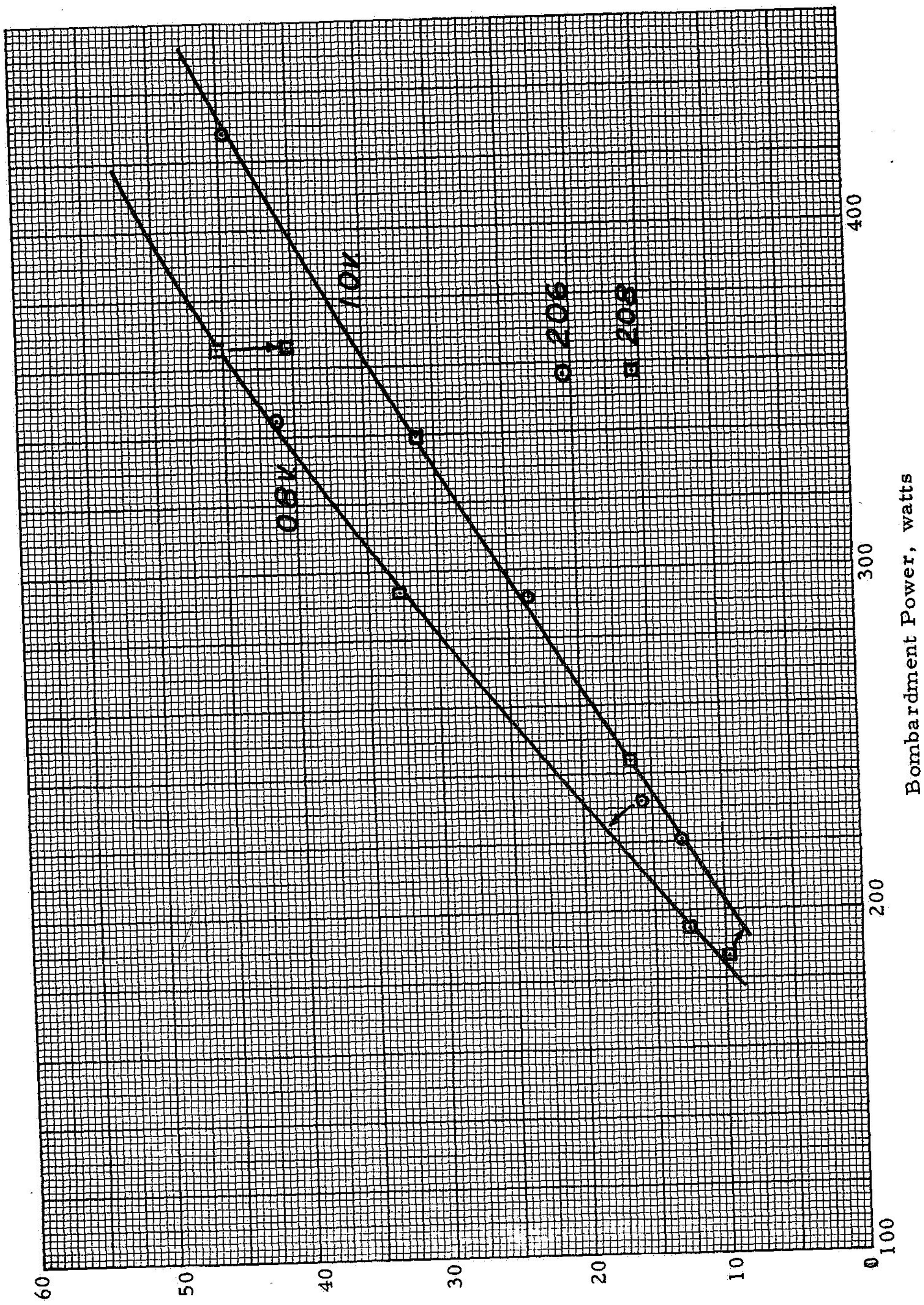


Figure 8

This was the first instance of converter degradation experienced under this program. To help diagnose the degradation, additional dynamic I-V characteristics were obtained for comparison with those recorded at the beginning of converter testing. Figure 9 shows the curves obtained at a reservoir temperature of 623°K, with a power input of 308 watts, and after 3.5 and 30.6 hours of testing, respectively. The curves show a shift along the voltage axis which is characteristic of an increase in collector work function. The amount of the shift is about 0.17 volt. There is no evidence to indicate that all degradation due to occur had in fact occurred at the end of 30.6 hours.

Because the converter was still operative at the end of these tests, it was delivered to JPL rather than dismantled for detailed examination. It is judged extremely likely, however, that when such an examination is conducted, it will reveal the presence of a sodium vapor leak from the heat pipe section into the converter envelope. Sodium has a thermionic work function of approximately 2.28 eV as compared with a value of 1.81 eV for cesium.* Thus a shift of 0.17 eV is quite reasonable even if differences in surface coverage are taken into account.

Sixteen-Converter Generator Design

The layout of the generator design prepared during this quarter is shown in Figure 10. Figure 10a is a view in the direction of the solar rays entering the cavity, Figure 10b is a sectional view along a cutting plane which contains the optical axis, Figure 10c is a rear view, and Figure 10d gives the list of parts and materials.

*Handbook of Chemistry and Physics, 46th Edition, The Chemical Rubber Company, 1965-1966.

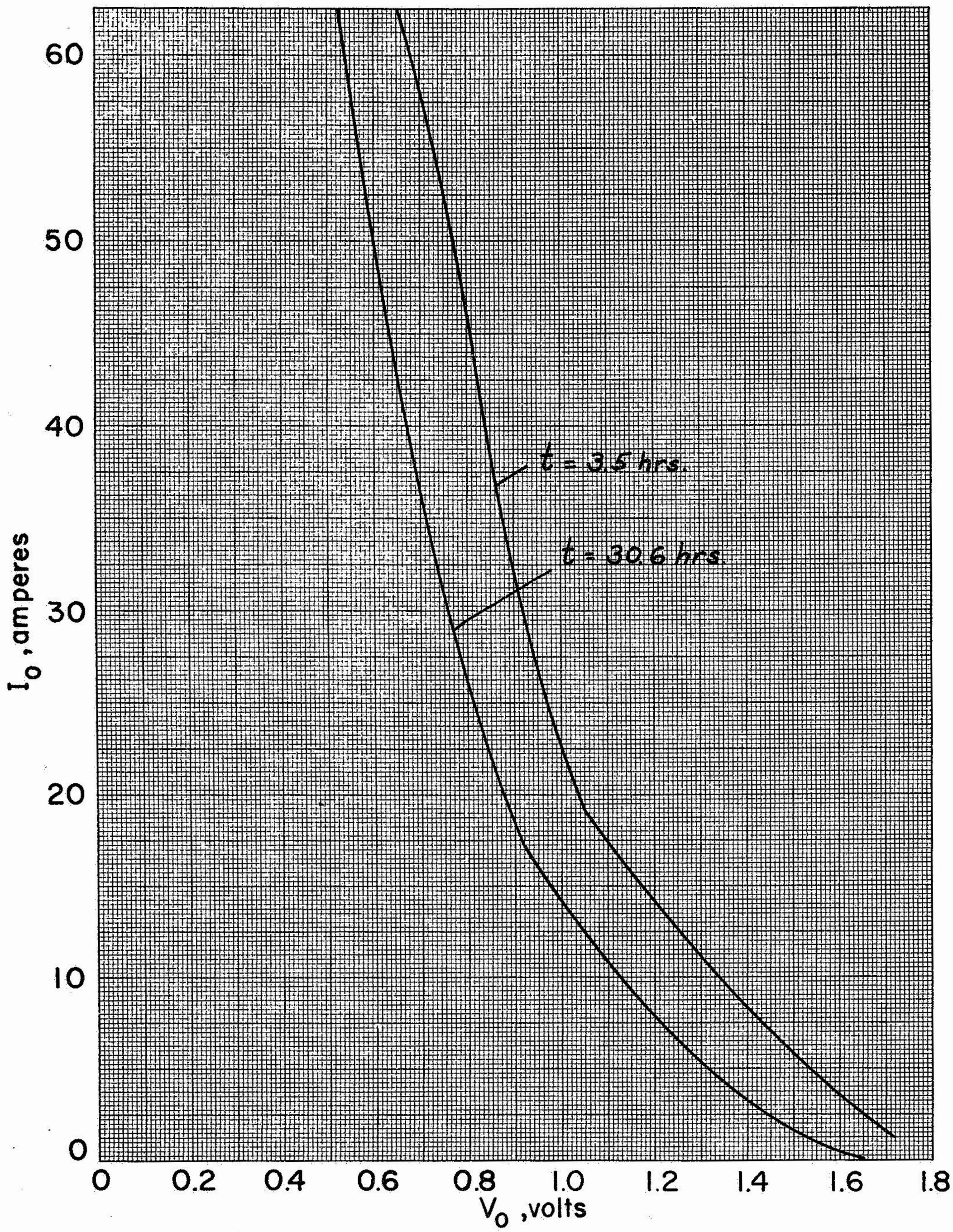

60
50
40
30
20
10
0
I_o ,amperes
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o ,volts
t = 3.5 hrs.
t = 30.6 hrs.

Figure 9

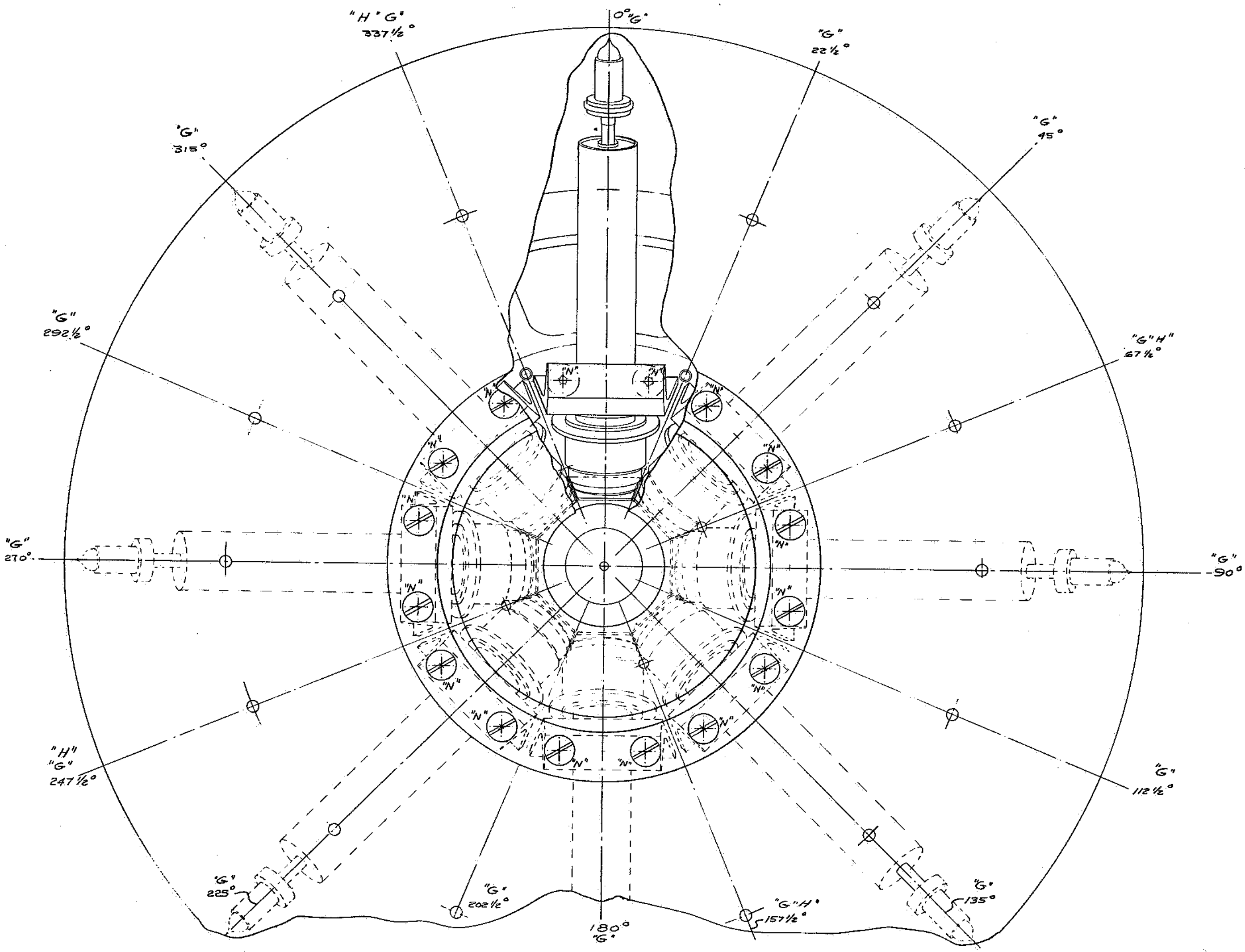

0° "G"
"H" "G" 337½°
"G" 22½°
"G" 315°
"G" 45°
"G" 292½°
"G" "H" 67½°
"G" 270°
"G" -90°
"H" "G" 247½°
"G" 112½°
"G" 225°
"G" 202½°
180° "G"
"G" "H" 157½°
"G" 135°
"N"

Figure 10 a

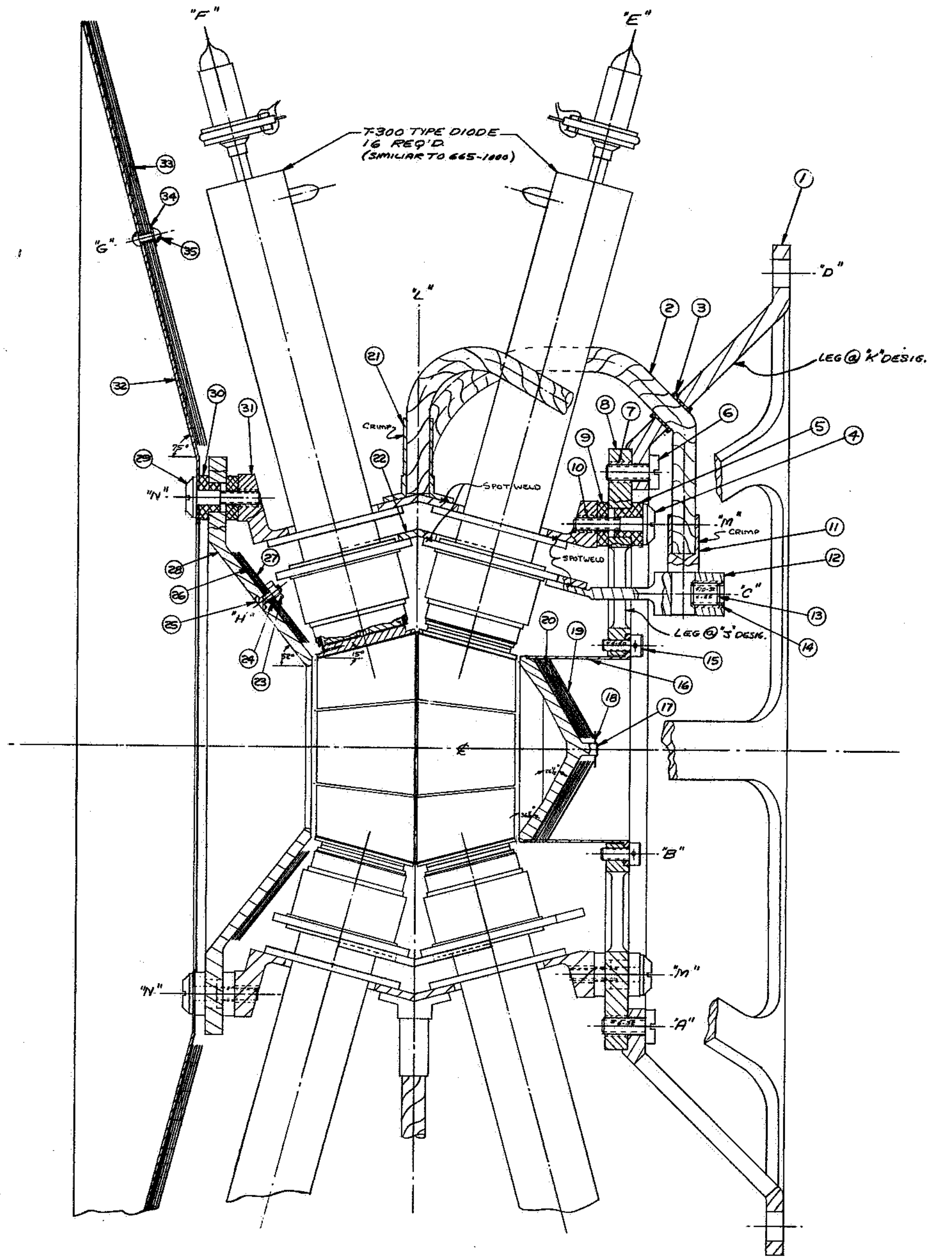


Figure 10b

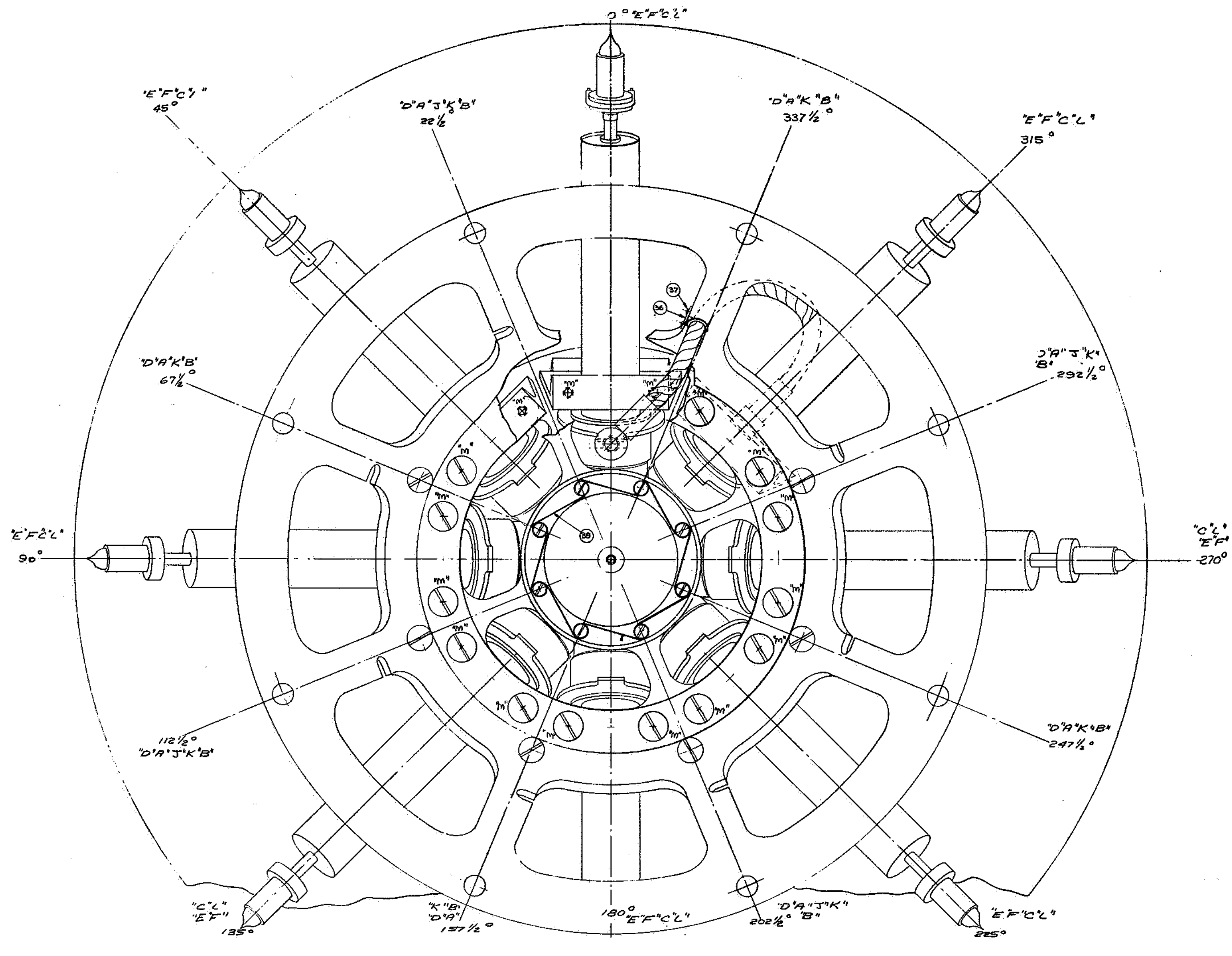


Figure 10c

PART	SIZE	REV	REQ	NOTES
LAYOUT & SUB-ASSEM				
1000				SHT. 1
1000				SHT. 2 5:1 LAYOUT OF CAVITY & EMITTER

7	SEE FIXTURE LAYOUTS (3090, 3190 ETC.) FOR FIXTURE INFORMATION.
6	UNK = UNKNOWN N.D.=NO DRAWING, PROCURE FROM THIS L.O.
5	DOTTED LINES INDICATE ROUGH OR PRELIMINARY MACHINING.
4	ALL MATING CORNERS & FILLETS ARE .015 X 45° CHFR. AND .010 R. RES.
3	MAX. PERMISSABLE TAP DRILL DEPTH AND MIN. PERMISSABLE FULL THREAD DEPTHS ARE SHOWN.
2	SECTION LOCATIONS DEFINED BY LETTER LOCATION AT END VIEW.
1	NOTES 2 THRU 7 APPLY UNLESS OTHERWISE SPECIFIED.

NOTES

	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V	W	Y	Z
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓									
2																						
V																						
∥																						
⊥																						
⊙																						

PART	SIZE	REV	REQ	MAT'L	NOTES
38	ND		AS REQD	Mo	.030 DIA. WIRE
37			16	SS	#0-80 X .125 LNG S.H.C.S.
36			8	SS	
35			16	Ta	
34			16	Ta	
33			5	Ta	
32			1	Ta	
31			8	Nb	
30			16	Al_2O_3	
29			16	Ta-10%W	
28			1	W	
27			1	Ta	
26			4	Ta	
25			4	Ta-10%W	
24			4	Ta	
23			4	Ta-10%W	
22			8	Nb	
21			8	Nb	
20			10	W	
19			1	Ta	
18			1	Ta	
17			1	W	
16			1	W	
15			8	Ta-10%W	
14	ND		8	SS	HELI COIL INSERT #3591-3CN-0190
13	ND		8	SS	#10-32 X .250 S.H. SET SCR.
12			8	Nb	
11			8	Nb	
10	ND		32	SS.	HELICOIL INSERT #3585-04CN-0168
9			32	Al_2O_3	
8			1	Nb	
7	ND		8	S.S.	HELI-COIL INSERT #3585-06CN-20T
6			8	Ta-10%W	
5			16	Al_2O_3	
4			16	Ta-10%W	
3			8	Al_2O_3	
2	ND		8	Cu	
1			1	Nb	

UNLESS OTHERWISE SPECIFIED

DECIMAL: .X ±.03, .XX ±.01, .XXX ±.005
FILLET RADIUS: .010 MAX.
THREADS: CLASS 2
* DIA. CONC. WITHIN ___ T.I.R.
ALL OTHER DIA. CONC. WITHIN .005 ___ T.I.R.
SURFACES TO BE PERP. WITHIN .005 ___ T.I.R.
SURFACES TO BE PAR. WITHIN .005 ___ T.I.R.
HOLE ANGULAR TOL. 0–2.0 RAD. ±0° 9'
2.0–4.0 RAD. ±0° 5'
ALL OTHER ANGULAR TOL. TO BE ±0° 30'
REMOVE ALL BURRS AND EDGES

THERMO ELECTRON ENGINEERING CORPORATION
85 FIRST AVENUE · WALTHAM, MASS. 02154

DRAWN	CHECKED	ENGINEER
MN 2-26-68		

TITLE:

SCALE: 2:1	FINISH: 63 RMS
NEXT ASSY.	SIMILAR TO

SIZE	DRAWING NUMBER	SHEET	REV
H	711-1000	1	

Figure 10d

The generator assembly consists of eight two-converter modules, having a front and a rear converter oriented at a common angle around the optical axis. These two converters are assembled by riveting or spot-welding them to a bent plate support, part No. 31, which electrically shorts their collector structures; thus, the converters in each module are wired in parallel. Each module is supported with electrically insulated attachments, so that the modules can be wired in series or in parallel at will. In the particular design presented, all modules are connected in series.

One advantage of this generator design is that the gap between the emitter pieces of the converters of a module can be closed since contact will not cause electrical shorting of converter output. By not insulating every converter, a substantial amount of insulating hardware is avoided, and a simpler, more compact and stronger structure is obtained. The nominal spacing between the surfaces of the cavity at different electrical potentials is 0.020 inch.

The modules are supported by front and rear one-piece metal rings, so that the complete assembly of modules and support rings forms a rigid frame. The design also provides for the simple removal of a converter module without the necessity of disassembling the entire generator. The front ring supports an entrance cone for the cavity, which helps to guide the solar energy into the cavity. Part No. 32 is an extension of the entrance cone, and its function is to protect the converters from concentrated sunlight in the event of accidental mis-orientation. The rear ring supports a cavity back-piece, made of tungsten, and shaped to reflect the sunlight striking it towards the heated faces of the converters. The rear ring is also attached to the generator support, which is a webbed conical structure, part No. 1.

New Technology

No items of new technology have been included in this report.

APPENDIX

THERMO ELECTRON
ENGINEERING CORPORATION

Sheet 1 of 5

Converter No. T-209 Run No. 1 & 2 Observer P. Brosan

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date May 1968		20	20	20	20	20	20	20	20	20	20
Time		11:33	13:25	13:43	13:50	13:57	14:05	14:17	14:24	14:39	14:43
Elapsed Time, Hours		0.8	2.6	2.9	3.1	3.2	3.3	3.5	3.6	3.8	3.9
T_O, °C (1)		1548	1497	1722	1724	1724	1727	1727	1727	1619	1620
T_O Corrected, °C		1549	1498	1723	1725	1725	1728	1728	1728	1620	1621
$\Delta T_{Bell\ Jar}$, °C		19	19	17	17	17	17	17	17	19	19
T_H, °C		1568	1517	1740	1742	1742	1745	1745	1745	1639	1640
ΔT_E, °C		13	15	13	15	15	18	18	18	12	13
T_E, °K		1828	1775	2000	2000	2000	2000	2000	2000	1900	1900
V_o, volts		0.322	0.522	—	—	—	—	—	—	—	—
I_o, amps		12.3	20.2	$\overline{12}$	~$\overline{20}$	$\overline{21}$	$\overline{31}$	$\overline{28}$	$\overline{28}$	$\overline{10}$	$\overline{12}$
P_o, watts		—	—	—	—	—	—	—	—	—	—
I-V Trace No.		—	—	1	2	3	4	5	6	7	8
T_R	mv	11.5	11.7	11.0	11.8	12.6	13.4	14.3	15.2	11.0	11.8
	°C	283	288	271	290	306	329	350	372	271	290
	°K	556	561	544	563	579	602	623	645	544	563
T_C	mv	20.0	20.5	21.2	21.5	23.0	24.4	24.6	24.7	20.1	20.5
	°C	485	497	513	520	555	588	593	595	487	497
	°K	758	770	786	793	828	861	866	868	760	770
T_C base inner	mv										
	°C										
T_C base outer	mv										
	°C										
$T_{Radiator}$	mv										
	°C										
V_{eb}, volts		985	985	975	975	971	967	967	967	983	981
I_{eb}, mA		160	160	221.1	227.3	256.3	294.8	307.9	308.5	177	189
$E_{Filament}$, volts		6.1	6.0	6.2	6.2	6.2	6.3	6.4	6.4	6.0	6.0
$I_{Filament}$, amps		26.2	26	26	26	26	27	27	27	26	26
$I_{Coll.\ Heater}$, amps		—	—	—	—	—	—	—	—	—	—
$I_{Res.\ Heater}$, amps		1.65	1.65	.65	1.65	1.66	2.01	2.27	2.64	~.65	1.79
Vacuum, 10^{-6} mm Hg		16	10	10	10	10	10	11	10	9	9
Measured Efficiency, %		157.6	157.6	215.6	221.6	248.9	285.1	297.7	298.3	174.0	185.4

NOTES: 1. Pyrometer Corrections +1.0°C at all temp 1600°C to 1800°C
Bell jar +19°C at 1600, +17 at 1700, +17 at 1800

Unit tested with double spiral filament.

$\Delta T_E = 10 + 0.25\ I_o$

Converter No. T-209 Run No. 2 & 3 Observer P. Brosens

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date May 1968		20	20	20	20	20	20	20	20	20	20
Time		14:55	15:07	15:16	15:21	15:35	15:41	15:48	15:53	16:00	16:04
Elapsed Time, Hours		4.1	4.3	4.5	4.6	4.8	4.9	5.0	5.1	5.2	5.3
T_0, °C		1622	1624	1624	1624	1521	1522	1524	1524	1525	1525
T_0 Corrected, °C		1623	1625	1625	1625	1522	1523	1525	1525	1526	1526
$\Delta T_{Bell\ Jar}$, °C		19	19	19	19	17	17	17	17	17	17
T_H, °C		1642	1644	1644	1644	1539	1540	1542	1542	1543	1543
ΔT_E, °C		15	17	17	17	12	13	15	15	16	16
T_E, °K		1900	1900	1900	1900	1800	1800	1800	1800	1800	1800
V_0, volts		—	—	—	—	—	—	—	—	—	—
I_0, amps		$\overline{22}$	$\overline{28}$	$\overline{28}$	$\overline{27}$	$\overline{8}$	$\overline{12}$	$\overline{20}$	$\overline{22}$	$\overline{24}$	$\overline{24}$
P_0, watts		—	—	—	—	—	—	—	—	—	—
I-V Trace No.		9	10	11	12	13	14	15	16	17	18
T_R	mv	12.6	13.4	14.3	15.2	11.0	11.8	12.6	13.4	14.3	15.2
	°C	306	329	350	372	271	290	306	329	350	372
	°K	579	602	623	645	544	563	579	602	623	645
T_C	mv	22.1	23.6	23.5	24.0	18.9	19.7	21.2	22.2	22.3	22.5
	°C	534	569	567	579	459	478	513	537	539	543
	°K	807	842	840	852	732	751	786	810	812	816
T_C base inner	mv										
	°C										
T_C base outer	mv										
	°C										
$T_{Radiator}$	mv										
	°C										
V_{eb}, volts		977	973	973	972	990	985	982	979	979	977
I_{eb}, mA		213.0	248.2	254.4	259.1	141.1	161.1	181.4	203.8	203.8	211.6
$E_{Filament}$, volts		6.1	6.2	6.2	6.2	5.9	6	6	6.1	6.1	6.1
$I_{Filament}$, amps		26	26	26	26	25	25	26	26	26	26
$I_{Coll.\ Heater}$, amps		—	—	—	—	—	—	—	—	—	—
$I_{Res.\ Heater}$, amps		1.94	2.07	2.62	3.06	1.78	1.92	2.26	2.59	2.80	3.21
Vacuum, 10^{-6} mm Hg		8	9	9	9	8	8	8	8	8	8
Measured Efficiency, %		208.1	241.5	247.5	251.8	139.7	158.7	178.1	199.5	199.5	206.7

NOTES:

THERMO ELECTRON
ENGINEERING CORPORATION

Converter No. T-209 Run No. 4 Observer P. Brosens

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date May 1968		20	—	—	—	—	—	—	—	—	20
Time		16:26	—	—	—	—	—	—	—	—	16:58
Elapsed Time, Hours		5.6	—	—	—	—	—	—	—	—	6.2
T_O, °C		1719	—	—	—	—	—	—	—	—	1719
T_O Corrected, °C		1720	—	—	—	—	—	—	—	—	1720
$\Delta T_{Bell\ Jar}$, °C		17	—	—	—	—	—	—	—	—	17
T_H, °C		1737	—	—	—	—	—	—	—	—	1737
ΔT_E, °C		10	—	—	—	—	—	—	—	—	10
T_E, °K		2000	—	—	—	—	—	—	—	—	2000
V_O, volts		2.237	—	—	—	—	—	—	—	—	1.889
I_O, amps		0	0	0	0	0	0	0	0	0	0
P_O, watts		—	—	—	—	—	—	—	—	—	—
I-V Trace No.		—	—	—	—	—	—	—	—	—	—
T_R	mv	10.0	11.0	12.0	12.5	13.0	14.0	14.5	15.0	16.0	17.0
	°C	246	271	295	307	319	343	355	367	391	414
	°K	519	544	568	580	592	616	628	640	664	687
T_C	mv	20.0	20.3	20.7	20.9	20.9	21.1	21.3	21.9	21.9	22.0
	°C	485	492	501	506	506	511	516	529	529	532
	°K	758	765	774	779	779	784	789	802	802	805
T_C base inner	mv										
	°C										
T_C base outer	mv										
	°C										
$T_{Radiator}$	mv										
	°C										
V_{eb}, volts		979	978	978	977	977	976	976	976	975	975
I_{eb}, mA		204.7	208.6	212.6	215.2	217.1	222.4	224.8	227.3	231.3	234.2
$E_{Filament}$, volts		6.0	—	—	—	—	—	—	—	—	6.1
$I_{Filament}$, amps		26	—	—	—	—	—	—	—	—	26
$I_{Coll.\ Heater}$, amps		—	—	—	—	—	—	—	—	—	—
$I_{Res.\ Heater}$, amps		0	1.36	1.78	2.03	2.22	2.71	2.97	3.14	3.59	4.00
Vacuum, 10^{-6} mm Hg		8	—	—	—	—	—	—	—	—	8
Measured Efficiency, %		200.4	204.0	207.9	210.2	212.1	217.1	219.4	221.8	225.5	228.3

NOTES:

Converter No. T-209 Run No. 5 & 6 Observer P. Brosey

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date May 1968		20	20	20	20	20	23	23	23	23	23
Time		17:11	17:19	17:37	17:45	17:51	12:45	12:57	13:06	13:15	13:26
Elapsed Time, Hours		6.4	6.5	6.8	6.9	7.0	10.5	10.7	10.8	11.0	11.2
T_0, °C		1682	1682	1682	1682	1682	1580	1580	1580	1580	1580
T_0 Corrected, °C		1683	1683	1683	1683	1683	1581	1581	1581	1581	1581
$\Delta T_{Bell\ Jar}$, °C		17	17	17	17	17	19	19	19	19	19
T_H, °C		1700	1700	1700	1700	1700	1600	1600	1600	1600	1600
ΔT_E, °C		12	13	14	18	22	11	12	12	13	18
T_E, °K		1961	1960	1959	1955	1951	1862	1861	1861	1860	1855
V_0, volts		1.400	1.200	1.000	.800	.600	1.400	1.200	1.000	.800	.600
I_0, amps		7.4	11.9	16.5	32.7	49.0	3.2	6.9	9.8	12.1	34.0
P_0, watts		10.4	14.3	16.5	26.2	29.4	4.5	8.3	9.8	9.7	20.4
I-V Trace No.		—	—	—	—	—	—	—	—	—	—
T_R	mv	12.4	13.1	13.5	14.2	14.1	11.3	12.1	12.7	13.2	13.9
	°C	304	321	331	348	345	278	297	312	324	341
	°K	577	594	604	621	618	551	570	585	597	614
T_C	mv	21.1	21.9	22.7	24.7	26.1	19.1	20.1	20.7	21.2	24.0
	°C	511	529	548	595	628	464	487	501	513	579
	°K	784	802	821	868	901	737	760	774	786	852
T_C base inner	mv										
	°C										
T_C base outer	mv										
	°C										
$T_{Radiator}$	mv										
	°C										
V_{eb}, volts		976	974	973	967	964	984	981	980	979	971
I_{eb}, mA		218.7	234.1	250.6	303.5	332.9	161.2	178.9	190.4	199.6	261.1
$E_{Filament}$, volts		6.1	6.1	6.2	6.3	6.4	5.9	6.0	6.0	6.0	6.2
$I_{Filament}$, amps		26	26	26	27	27	25	25.5	26	26	26.5
$I_{Coll.\ Heater}$, amps		—	—	—	—	—	—	—	—	—	—
$I_{Res.\ Heater}$, amps		1.98	2.19	2.36	2.42	1.72	1.64	1.89	2.19	2.28	2.17
Vacuum, 10^{-6} mm Hg		8	8	8	8	8	5	5	5	5	5
Measured Efficiency, %		213.4	228.0	243.8	293.5	320.9	158.6	175.5	186.6	195.4	253.5

NOTES:

THERMO ELECTRON
ENGINEERING CORPORATION

Converter No. T-209 Run No. 7 & 8 Observer P. Brosens

VARIABLE		1	2	3	4	5	6	7	8	9	10
Date May 1968		23	23	23	23	23		23	24	24	24
Time		13:43	13:55	14:04	14:34	14:44		16:01	8:56	9:36	9:44
Elapsed Time, Hours		11.5	11.7	11.8	12.3	12.5		13.1	29.9	30.6	30.7
T_O, °C		1782	1782	1782	1782	1782		1682	1668	1706	1727
T_O Corrected, °C		1783	1783	1783	1783	1783		1683	1669	1707	1728
$\Delta T_{Bell\ Jar}$, °C		17	17	17	17	17		17	?	?	?
T_H, °C		1800	1800	1800	1800	1800		1700	—	—	—
ΔT_E, °C		14	15	18	20	24		18	—	—	—
T_E, °K		2059	2058	2055	2053	2049		1955	—	—	—
V_o, volts		1.400	1.200	1.000	.800	.600		.650	.600	—	—
I_o, amps		14.3	21.0	31.3	40.4	55.7		32.7	32.7	27	27
P_o, watts		20.02	25.20	31.3	32.3	33.4		21.25	19.6	—	—
I-V Trace No.		—	—	—	—	—		—	—	19	20
T_R	mv	14.0	14.0	14.3	14.8	15.3		14.2	14.2	14.3	14.3
	°C	343	343	350	362	374		348	348	350	350
	°K	616	616	623	635	647		621	621	623	623
T_C	mv	23.9	24.5	25.6	26.9	28.3		25.0	25.0	24.9	25.2
	°C	576	590	616	647	680		602	602	600	607
	°K	849	863	889	920	953		875	875	873	880
T_C base inner	mv					(1)		(2)	(3)		(4)
	°C										
T_C base outer	mv										
	°C										
$T_{Radiator}$	mv										
	°C										
V_{eb}, volts		967	966	963	961	956		970	970	970	969
I_{eb}, mA		300.2	320.8	352.5	381.2	425.7		303.0	303.9	307.9	321.9
$E_{Filament}$, volts		6.2	6.2	6.3	6.4	6.4		6.3	6.1	6.2	6.2
$I_{Filament}$, amps		26	26.5	26.5	27	27		27	26	26	26
$I_{Coll.\ Heater}$, amps		—	—	—	—	—		—	—	—	—
$I_{Res.\ Heater}$, amps		2.21	2.12	2.04	2.12	2.08		2.41	2.27	2.34	2.36
Vacuum, 10^{-6} mm Hg		5	5	6	6	6		11	4	4	4
Measured Efficiency, %		290.3	309.9	339.4	366.3	407.0		293.9	294.8	298.7	311.9

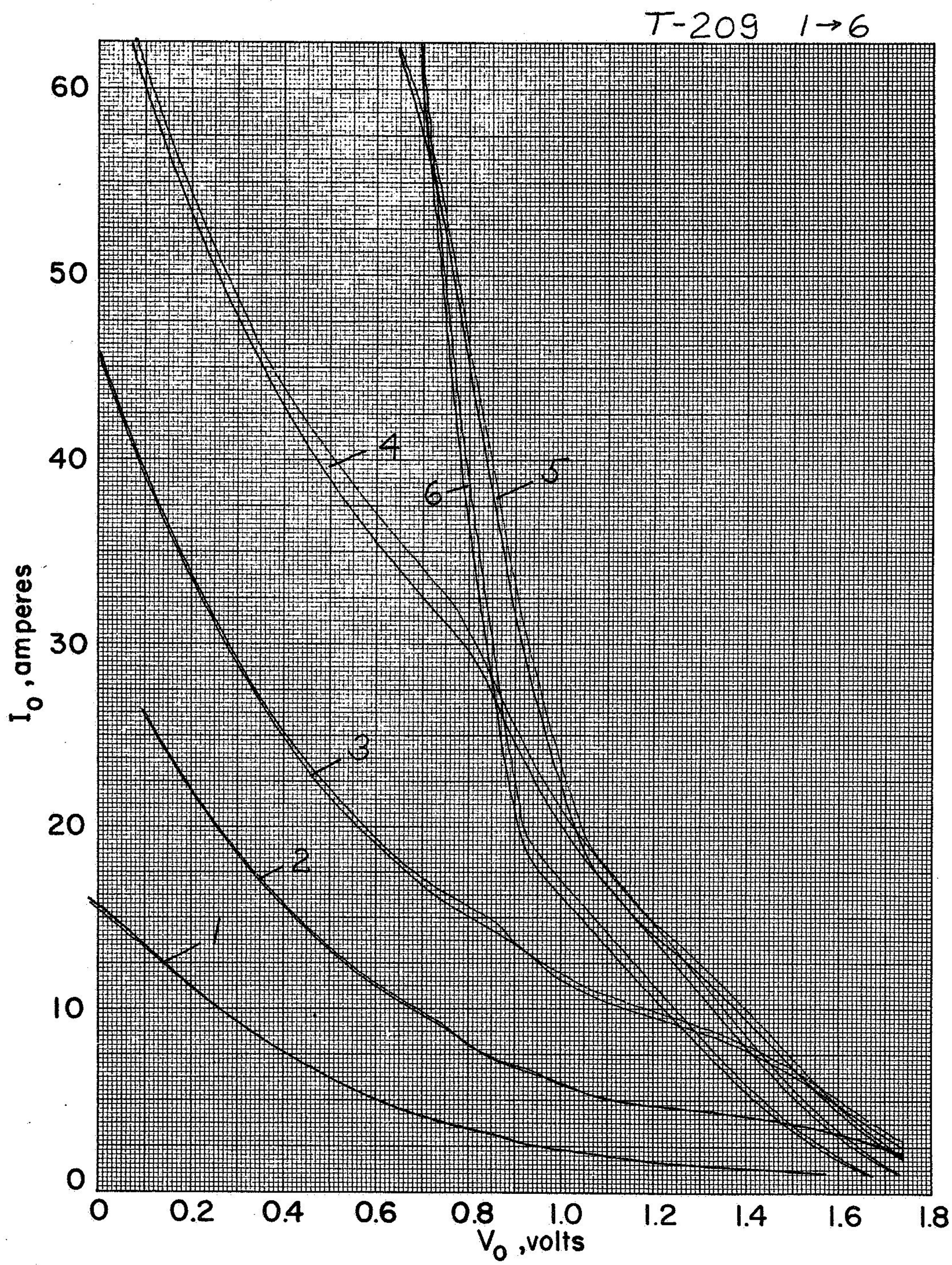
NOTES: (1) OUTPUT SEEMED TO DEGRADE SLIGHTLY, COULD NOT REPRODUCE DATA PT OF P.4 No.4 @ 1700°C, 0.8 V – DECIDED TO SHUT-OFF AND EXAMINE VOLTAGE TAP CONNECTIONS – VOLTAGE TAPS WERE FOUND FIRMLY ATTACHED – PUMPED SYSTEM BACK DOWN TO RUN AT THE CONDITIONS OF DATA PT. OF P.4 No.4.

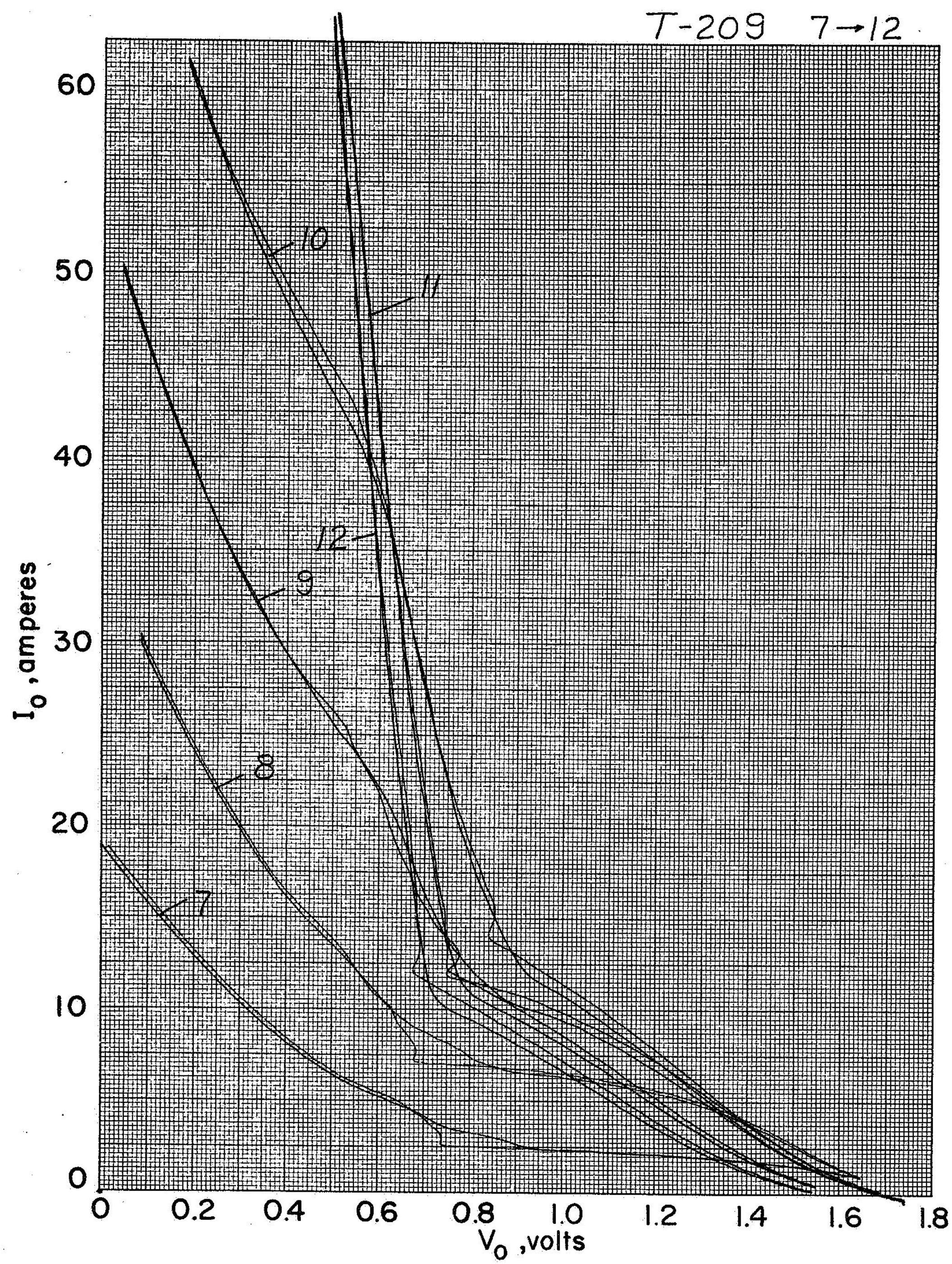
(2) LEFT TO RUN OVERNIGHT.

(3) PREPARED FOR CONVERTER MAPPING, REPEAT OF I-V No. 5

(4) END OF TEST

8392


T-209 1→6
60
50
40
30
20
10
0
I_o, amperes
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts
1
2
3
4
5
6


T-209 7→12
60
50
40
30
20
10
0
10
11
12
9
8
7
I_o, amperes
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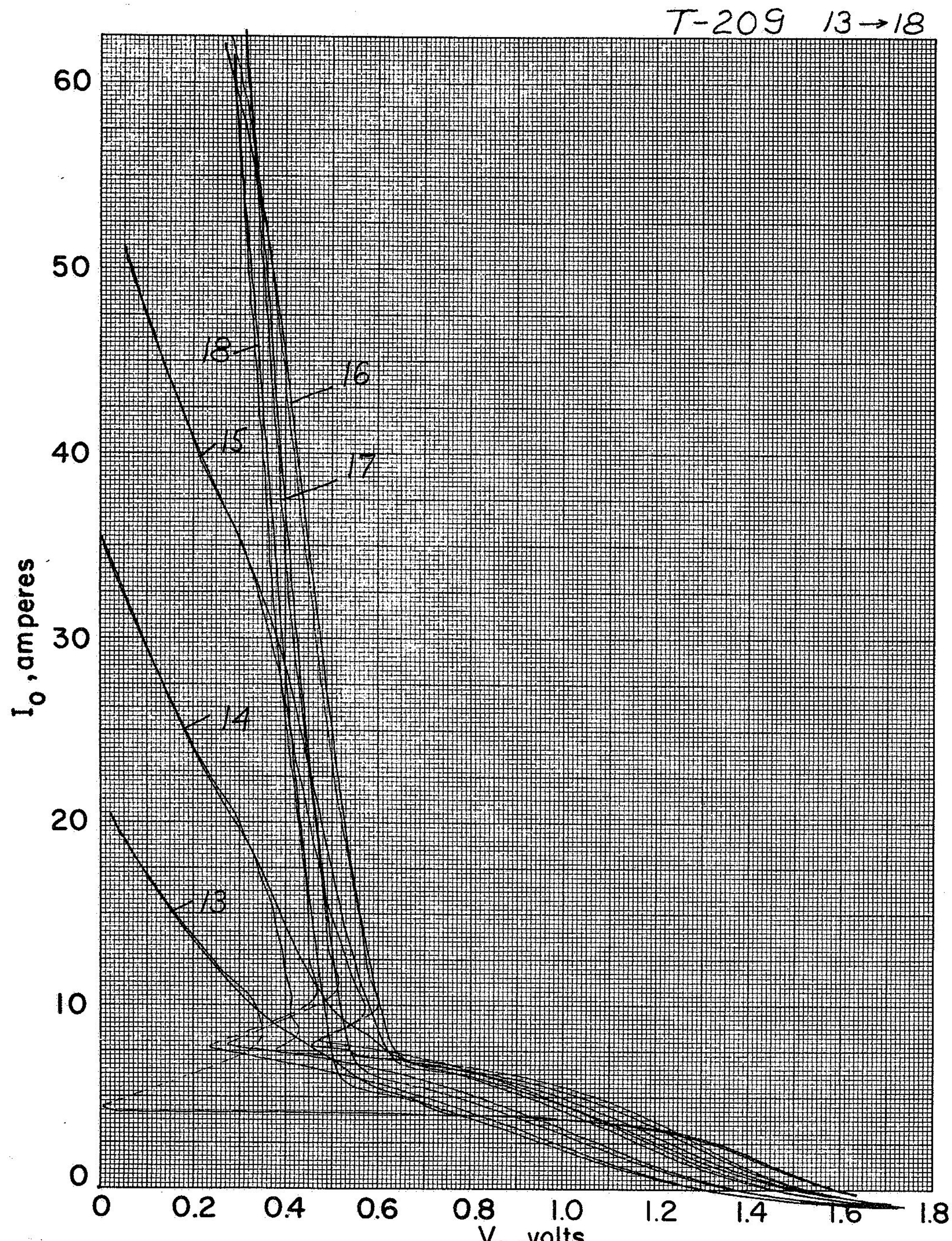
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts

8390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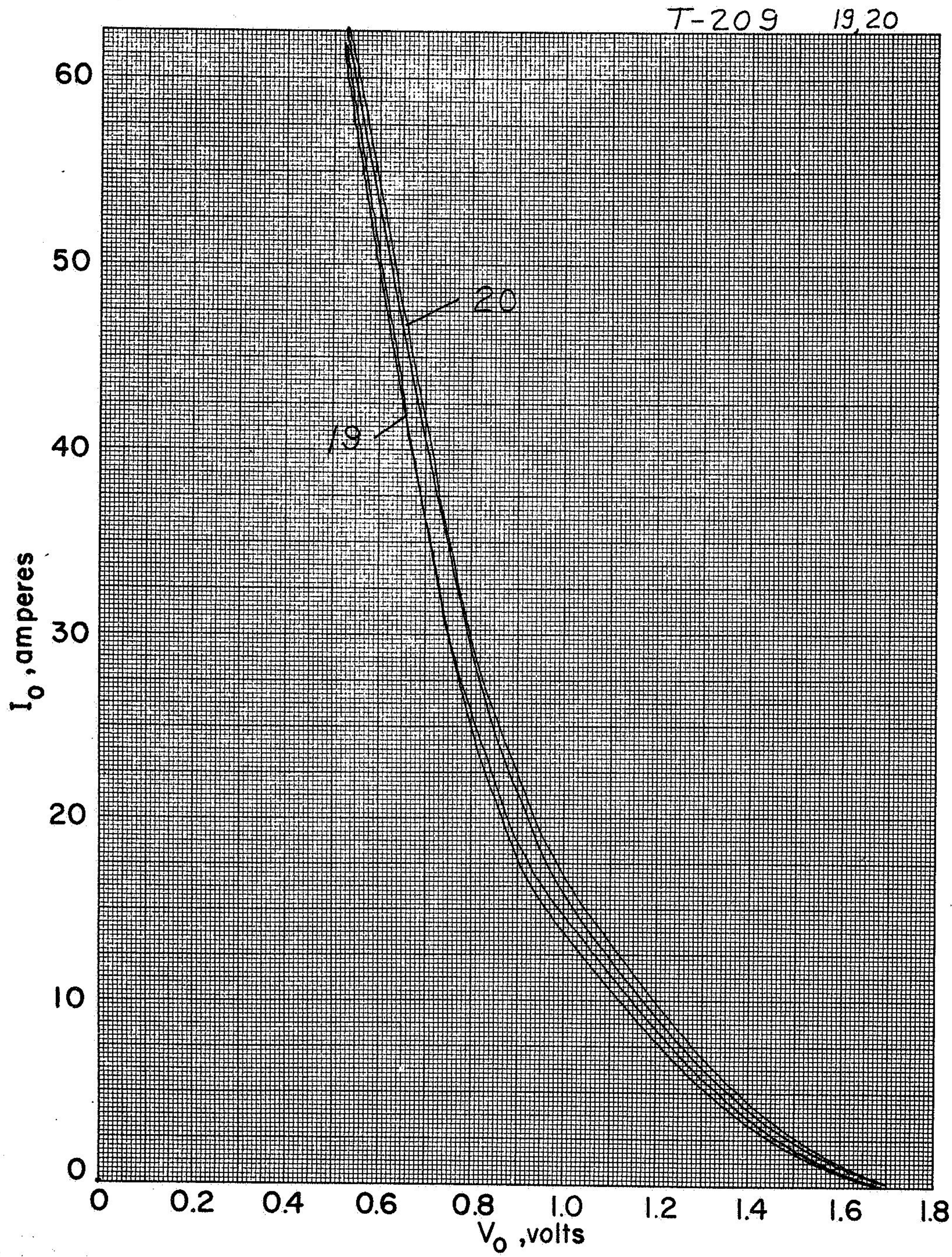
60
50
40
30
20
10
0
I_o, amperes
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts
18
16
15
17
14
13

8389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60
50
40
30
20
10
0
I_o, amperes
20
19
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
V_o, volts